Infestation dynamics of *Phyllocnistis citrella* Stainton (Lepidoptera: Phyllocnistidae) on Mosambi (*Citrus sinensis*) and its relation with important weather factors in Jammu, India

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Abstract: The objective of this work is to study the seasonal variation of percentage infestation, and effect of important weather factors *viz.* rainfall, relative humidity and temperature on the population of Citrus leaf miner, *Phyllocnistis citrella* Stainton in J&K State of India. Seasonal abundance of Citrus leaf miner was investigated fortnightly in an orchard of Mosambi (*Citrus sinensis*) from March 2005 to Feb 2008, located in Jammu. There were three infestation peaks in a year that coincided with the availability of new vegetative flush *viz.* mid April, mid July and mid September. Correlation analysis indicated that morning, afternoon and average relative humidity were negatively correlated, whereas, average rainfall, and maximum, minimum and average temperature were positively correlated with the population of citrus leaf miner. Rainfall and temperature had significant positive correlation with the population infestation. In general, population of *P. citrella* can not be predicted simply by observing the relative humidity of a particular area. However, rainfall and temperature all play important roles in affecting the pest infestation.

Key words: *Phyllocnistis citrella*; *Citrus sinensis*; infestation dynamics; weather factors; seasonal variation

1 INTRODUCTION

Citrus leaf miner, *Phyllocnistis citrella* Stainton, originated in Southeast Asia is a major citrus pest in the Old World. It is widespread in Asia (Clausen, 1931) and is known from East Africa (Sudan) to Yemen (Badawi, 1967), through Southern Asia, Saudi Arabia to India (Fletcher, 1920) and Indonesia (Kalshoven, 1981), north to Hong Kong and Taiwan (Chiu, 1985), Philippines (Sasscer, 1915) and southern Japan (Clausen, 1927). It is also found in New Guinea and nearby Pacific Islands and Australia (Beattie, 1989). It is polyphagous and feeds primarily on citrus plants of family, Rutaceae including *Aegle marmelos* (L.) Corr. Serr., *Aiton* sp. (Fletcher 1920) and *Atalania* sp. (Sasscer, 1915). Other reported hosts include *Jasminum sambac* (L.), *Loranthus* spp. (Reinking and Groff, 1921), *Murraya paniculata* (L.) Jack and *Alseodaphne semecarpifolia* Nees (Latif and Yunus, 1951).

Citrus leaf miner damages citrus by mining the underside of young citrus leaves and can also be observed on the upper leaf surfaces when a single leaf is attacked by many larvae. The leaf mining results in leaf deformation, curling, partial chlorosis, necrosis, drop and possible stem dieback, and ultimately impairs the tree's photosynthetic capacity. A little infestation is also seen on the twigs. Citrus leaf miner also feeds on fruit but generally this type of feeding is not a significant problem. Mining of spring flush is more damaging than fall flush since the spring flush is primarily responsible for supporting fruit development. Plants with three years of age or less are especially susceptible to their damage. Usually a minimum of one mine is seen on a leaf, but 2 - 3 mines are also observed during severe infestation, and as many as nine mines have been reported on a leaf (Knapp *et al.*, 1995). Moderate infestation of 1 - 2 larvae per leaf in seven year old trees was sufficient to lower the yields by 30% - 40% in the following year (Coleman, 1994). 34% - 36% and even up to 90% - 94% of loss to young plants (Sontakay and Gupta, 1945) has been reported by Punjab and Madhya Pradesh. Additionally, the mines provide an entry point for a number of plant pathogens including citrus canker. It greatly exacerbates the severity of citrus canker caused by *Xanthomonas axonopodis* pv. *citri*. When the galleries become contaminated with citrus canker bacteria, numerous infections can occur, resulting in tremendous inoculum production and canker infection. Surveys conducted under field conditions in different countries have shown up to 75% rates of citrus canker infestation in citrus leaves

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when the miner is present (Sohi and Sandhu, 1968; Heppner, 1993). Recently citrus canker has been detected in Mosambi plantations in a substantial amount in the state of J&K, India.

Many studies on the seasonal variation of populations of *P. citrella* have been conducted in India (Batra and Sandhu, 1981), Mexico (Bautista-Martinez *et al.*, 1998), USA (Legaspi *et al.*, 1999), Europe (Urbaneja *et al.*, 2000) and Brazil (Greeve and Redaelli, 2006) in the past 30 years. The severity of *P. citrella* depends upon the timing of leaf miner infestation in relation to seasonal flushing patterns, which differ among regions, varieties and plant age (Knapp *et al.*, 1995). In southern India, Singh and Azam (1986) observed that the larvae remain active throughout the year but heavy infestation occurred during February and March. Screening of citrus germplasm against leaf miner in mid hills eastern India suggested the peak activity was during February – March and June (Thakur and Govind, 1991). In China and Australia, *P. citrella* caused minor damage to spring flushes (Binglin and Mingdu, 1996). In south Florida, oviposition number was lower in the winter than in other seasons due to nighttime temperature (Pena *et al.*, 1996). In Mediterranean climatic conditions, the population proliferates only in the warmer months of the year and spring flushes usually escape damage (Costa-Comelles *et al.*, 1996). In Argentina, the population increased during spring and summer, but declined during fall, and disappeared during winter (Diez *et al.*, 2006).

Earlier research reports in Asia have been focused on the population dynamics and seasonal abundance of *P. citrella* on different citrus cultivars (Batra and Sandhu, 1981; Huang *et al.*, 1989). But the prediction of the population on the basis of important weather parameters needs to be revised again in India. The objective of this work is to study the seasonal abundance, and to correlate the important weather factors *viz.* rainfall, relative humidity and temperature with the population so as to find out the role of weather factors and to make an effort to develop an integrated management program for Citrus leaf miner in J&K State of India.

2 MATERIALS AND METHODS

2.1 Infestation dynamics of *P. citrella*

Data for seasonal abundance and population of the pest were collected fortnightly for three consecutive years *i.e.* March 2005 – Feb. 2008 in a plain irrigated orchard land of Mosambi (*Citrus sinensis*) having 500 plantations, 5 years old, with inter tree distance of about 3.65 m located in Vijaypur (District Samba) (32°34′N and 75°01′E; 360 m). For the purpose of sampling, the field was divided into five blocks covering all the four directions and one from the centre. From each block, two trees were randomly selected. Thus, the population records were made on total of 10 randomly selected trees of uniform spread from all the five blocks from the study area and marked for recording observations. The all selected trees were kept free from insecticidal treatments throughout the periods of study. Three branches (10 cm each) one each from upper, middle and lower strata from each of the four geographical directions were selected at random for recording the prevalence of the insect on one tree. The number of Citrus leaf miner larvae per shoot was counted and recorded fortnightly. Percentage infestation was calculated by dividing the number of leaf miners with total number of leaves per shoot (6 ± 1.56 leaves per 10 cm shoot). Fortnightly meteorological data with regards to temperature (maximum, minimum and average), relative humidity (morning, afternooon and average) and average rainfall were obtained from meteorological department, Sher-e-Kashmir University of Agricultural Sciences and Technology (SKUAST), Jammu, 25 km far from the experimental area.

2.2 Statistical analysis

Mean infestation percentage was transformed into arcsin transform value. Data of three years were pooled together to find the mean population dynamics of the pest. For analysis of infestation dynamics of the pest population with meteorological data (*viz.* average rainfall, morning relative humidity, afternoon relative humidity, average relative humidity, minimum temperature, maximum temperature and average temperature), the data were subjected to both linear and multiple analyses. Multiple correlation studies were conducted to understand the influence of important weather factors prevailing during the preceding fortnight on population build-up of Citrus leaf miner in the next fortnight for precise and timely planning of management strategies to suppress the important pests. Statistical analysis was conducted by using SPSS software version 12.0.

3 RESULTS

3.1 Infestation dynamic

Infestation of *P. citrella* had three peaks on Mosambi (*C. sinensis*) in a whole year during the experimental period (Fig. 1). The first peak was attained during the first fortnight of April in all the three years, however, there was a difference in the intensity of infestation which was maximum during 2007 (376 ± 1.23 larvae per 693 leaves; 54.32 per cent). Thereafter, there was a steep decline in the infestation till May. During June the population started rising, and reached the second peak during June-July. In 2005, the second peak was attained during the first fortnight of July with 21.54 per cent infestation (133 ± 1.67 larvae per 621 leaves). However, during 2006, it was observed in the second fortnight of July (120 ± 1.09 larvae per 568 leaves; 21.10 per cent). During 2007, it was seen that the second peak was attained earlier than the previous two years and the percentage infestation reached 32.21 per cent (226 ± 1.65 larvae per 703 leaves) during the second fortnight of June. The third peak was achieved during the first fortnight of September in 2005 (122 ± 1.09 larvae per 608 leaves; 20.18 per cent) and in 2007 (300 ± 1.62 larvae per 693 leaves; 43.21 per cent). However, it was attained a little late in 2006 which was seen during the end of September with the percentage infestation of 37.89 per cent (207 ± 1.78 larvae per 547 leaves). Thereafter, a gradual decline in the population was noticed till the first fortnight of January. A slight increase in the infestation was observed during the second fortnight of January and then a rapid build up during February.

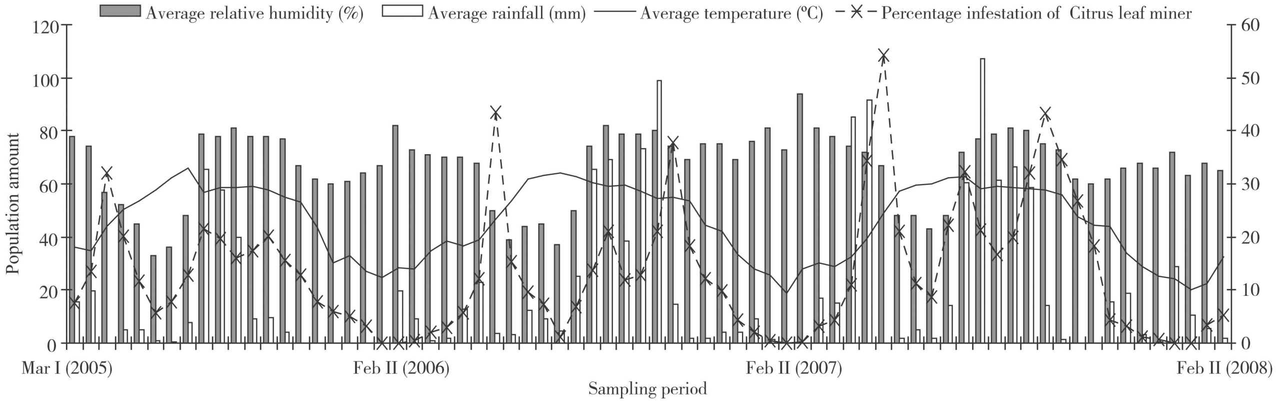

Fig. 1 Population dynamics of *Phyllocnistis citrella* (Citrus leaf miner) during different months in relation to average temperature (solid line), average rainfall and average relative humidity (bars) from March 2005 – February 2008

The mean infestation dynamics of *P. citrella* on Mosambi is shown in Fig. 2. Citrus leaf miners were found on Mosambi on all the sampling dates, however the percentage infestation varied during the three studied years. Pooled data of three years indicated a sharp increase in population infestation at the end of March resulting in a first peak formation during the first fortnight of April with the value 43.29 per cent (262 ± 1.54 larvae per 603 leaves). During early July an increase in the leaf miner infestation was observed which resulted in another small peak during the second fortnight of July (123 ± 1.28 larvae per 643 leaves; 19.17 per cent). A third peak (181 ± 1.43 larvae per 616 leaves; 29.32 per cent) obtained during second fortnight of September.

3.2 Effect of weather factors

Correlation analysis for the three year pooled data indicated that afternoon relative humidity has a positive correlation ($r = 0.06$, $n = 120$, $P = 0.760$) with the population infestation, and morning ($r = 0.03$, $n = 120$, $P = 0.88$) and average relative humidity ($r = 0.07$, $n = 120$, $P = 0.737$) has a negative correlation, though not significantly correlated. Average rainfall also had a positive correlation with the population infestation ($r = 0.341$, $n = 120$, $P = 0.103$). For the whole period there was a highly significant positive correlation between the *P. citrella* infestation and maximum, minimum and average temperature ($P \leqslant 0.01$).

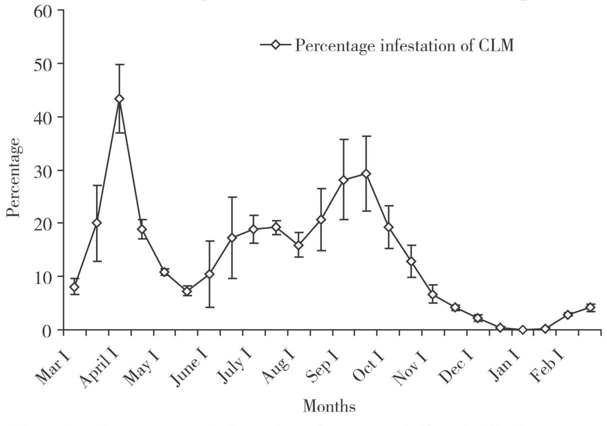

Fig. 2 Percentage infestation (mean ± *SE*) of *Phyllocnistis citrella* per shoot on Mosambi for three years *viz.* March 2005 – February 2008

CLM: Citrus leaf miner (*Phyllocnistis citrella*).

Table 1 Regression equation and coefficient of determination (r^2) of population data of *Phyllocnistis citrella* on Mosambi (*Citrus sinensis*) at Vijaypur (District Samba) during March 2005 to February 2008

Period	Regression equation							
	Average rainfall X_1	Morning relative humidity X_2	Afternoon relative humidity X_3	Average relative humidity X_4	Maximum temperature X_5	Minimum temperature X_6	Average temperature X_7	Multivariate factors
Mar 05 – Feb 06	$15.17 + 0.19X_1$ $(0.164)^{*}$	$23.83 - 0.07X_2$ (0.015)	$15.50 + 0.04X_3$ (0.006)	$17.94 - 0.006X_4$ (0.001)	$-10.49 + 0.94X_5$ $(0.413)^{**}$	$4.62 + 0.82X_6$ $(0.510)^{**}$	$-3.63 + 0.93X_7$ $(0.490)^{**}$	$-50.20 + 0.22X_1 - 0.82X_2 - 1.84X_3 + 2.83X_4 - 2.06X_5 - 2.62X_6 + 6.11X_7 (0.744)^{**}$
Mar 06 – Feb 07	$14.88 + 0.12X_1$ (0.119)	$23.20 - 0.06X_2$ (0.010)	$23.10 - 0.10X_3$ (0.032)	$24.50 - 0.10X_4$ (0.024)	$-1.82 + 0.67X_5$ $(0.257)^{*}$	$5.68 + 0.70X_6$ $(0.292)^{**}$	$-0.10 + 0.76X_7$ $(0.295)^{**}$	$-106.03 + 0.08X_1 - 0.08X_2 - 1.38X_3 + 2.09X_4 + 0.68X_5 - 2.32X_6 + 3.48X_7 (0.670)^{**}$
Mar 07 – Feb 08	$19.81 + 0.09X_1$ (0.056)	$42.53 - 0.24X_2$ (0.040)	$4.30 + 0.36X_3$ $(0.169)^{*}$	$7.30 + 0.22X_4$ (0.035)	$-15.89 + 1.30X_5$ $(0.529)^{**}$	$3.25 + 1.18X_6$ $(0.507)^{**}$	$-6.89 + 1.27X_7$ (0.527)	$-111.19 + 0.006X_1 + 1.36X_2 + 1.65X_3 - 2.12X_4 + 6.72X_5 - 0.10X_6 - 5.14X_7 (0.792)^{**}$
Pooled (Mar 05 – Feb 08)	$16.25 + 0.15X_1$ (0.116)	$21.22 - 0.02X_2$ (0.001)	$16.90 + 0.04X_3$ (0.004)	$23.20 - 0.06X_4$ (0.005)	$-12.26 + 1.08X_5$ $(0.514)^{*}$	$3.66 + 0.96X_6$ $(0.505)^{**}$	$-5.06 + 1.06X_7$ $(0.521)^{**}$	$-150.64 + 0.07X_1 + 0.009X_2 - 1.02X_3 + 1.89X_4 + 2.57X_5 - 3.22X_6 + 3.03X_7 (0.826)^{**}$

* Significant at the 0.05 level; ** Significant at the 0.01 level (2 tailed). Numbers in parentheses are r^2 value.

When all the weather factors were regressed together against percentage infestation of Citrus leaf miner, results reveal that afternoon relative humidity and minimum temperature have a negative association with the percentage infestation. Other weather parameters showed a positive association. Coefficient of determination value (r^2) as high as 0.792 during the year 2007 revealed that these weather conditions had greater impact on the infestation of Citrus leaf miner (Table 1).

4 CONCLUSIONS AND DISCUSSION

The highest infestation during 2007 was apparently due to heavy rainfall which led to the sufficient availability of fresh vegetative flush. A steep decline in the population infestation till May coincided with the increase in temperature and decrease in relative humidity. However, with the commencement of rainfall during June the population infestation started rising and reached the second peak during June – July, and onset of regular rains during monsoon period resulted in the formation of the third peak during September that coincided with the availability of new flush, decrease in temperature and increase in relative humidity. It was observed that the severity of infestation was more pronounced on spring flush (April) rather than on autumn flush (September). Fig. 1 showed that the three peak infestation period coincided with the amount of rainfall received during that period that helped in the resurgence of new flush, thus showing the positive association with average rainfall. Thus, it is evident that there were three peaks that coincided with the availability of new vegetative flush but the fluctuation in the population during the study period of three years could be due to the fluctuations in the weather factors, suggesting that the population of Citrus leaf miner is also affected by the weather factors besides the availability of new flush.

Rehman and Yunus (1945) noticed the peak periods of Citrus leaf miner infestation from March to May and again in September to November in the former western Punjab (now the Punjab province in Pakistan). Pandey and Pandey (1964) observed increased activity of the leaf miner from August to November. In Punjab, Batra and Sandhu (1981) observed that this pest poses a serious threat to tender foliage of Citrus during March to May and August to October when there is maximum new growth and revealed that the population showed two peaks, *i. e.* in April – May and August – September. On the contrary, Lakra *et al.* (1984) noticed a higher larval and pupal population per sampling unit during September to December, whereas it was low during March and June. However, in the current study there was no population increase from mid September to December and the larval population was more pronounced during Spring (March – April) possibly due to decrease in temperature. In Argentina, the highest population levels of *P. citrella* were observed between January and March, while the lowest incidence occurred in the months of August through December and April through July (Diez *et al.*, 2006). In Florida (Pena *et al.*, 1996) and southern Texas (Legaspi *et al.*, 1999) population densities increase from spring to fall and decline during the winter.

In general, there were three peaks that coincided with the availability of new vegetative flush *viz.* mid April, mid July and mid September in J&K State of India. Population of *P. citrella* can not be predicted simply by observing the relative humidity of a particular area. Relative humidity does not help in the population buildup of *P. citrella* as has been observed. However, rainfall and temperature play important roles in affecting the pest infestation where increase in rainfall and temperature increase the infestation of *P. citrella* because of the resurgence of the vegetative flush after rain.

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印度查谟地区甜橙上柑桔潜叶蛾为害动态及其与重要气候因子的关系

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摘要：本研究旨在揭示印度查谟柑桔潜叶蛾 *Phyllocnistis citrella* Stainton 为害甜橙 *Citrus sinensis* 的季节性变化，以及降雨量、相对湿度和温度等重要的气候因子对其种群的影响。本文对不同季节印度查谟的一个甜橙园里的柑桔潜叶蛾丰度进行了调查，从2005年3月到2008年2月每两周调查一次。柑桔潜叶蛾在一年内有3个为害高峰，分别是4月中旬、7月中旬和9月中旬，这与甜橙新营养梢的生长期相吻合。相关分析表明，上午和下午的相对湿度和平均相对湿度与柑桔潜叶蛾的数量呈负相关；然而，平均降雨量、最高气温、最低气温和平均气温与柑桔潜叶蛾的数量呈正相关。降雨量和温度与柑桔潜叶蛾为害程度呈显著正相关。总之，柑桔潜叶蛾的数量不能简单地通过观察某一特殊地区的相对湿度来预测，而降雨量和温度在影响虫害方面均起着重要的作用。

关键词：柑桔潜叶蛾；甜橙；虫害动态；气候因素；季节变化

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